Materials Test Station Physics Needs

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Outline

- Materials Test Station overview
- Code needs
  - MCNPX
  - CINDER'90
- Nuclear data needs
  - He production from actinide fission
  - New 150-MeV evaluations
- Damage modeling at high energy

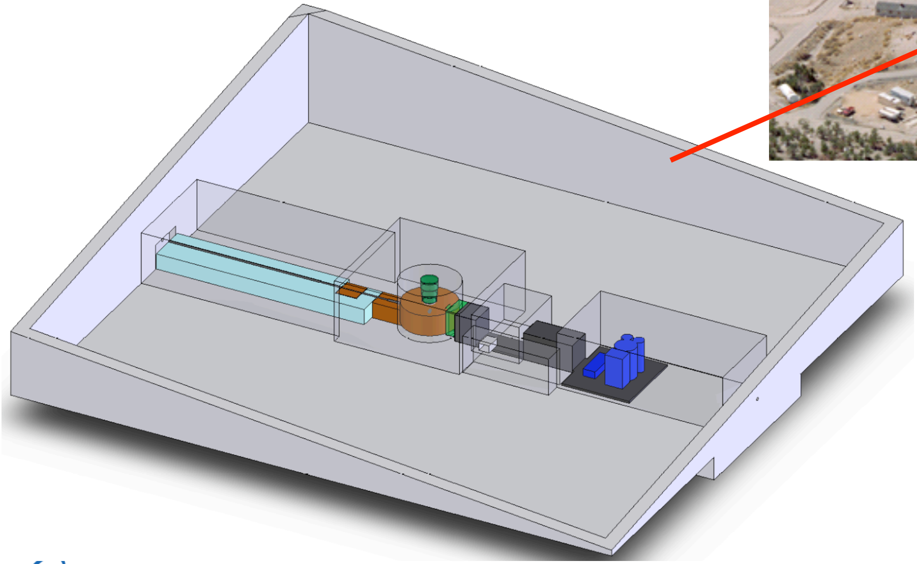
The LANSCE Materials Test Station will provide a domestic fast spectrum irradiation capability

- With the termination of the Fast Flux Test Facility at Hanford, there is no longer a U.S.-based fast neutron spectrum irradiation facility
- There are a limited number of viable facilities abroad:
  - PHENIX (France, due to close by end of this decade)
  - JOYO (Japan)
  - BOR-60 (Russia)
- The AFCI program has been successful in securing irradiation services abroad, but the process is time consuming
- A single 60-day JOYO irradiation of a materials assembly costs ~$1M for irradiation services only
- The ideal technical solution is the construction of a new fast reactor, but the time horizon and cost are uncertain
  - The earliest date to start materials testing in a new fast reactor is 2018
  - A new reactor is ~$1B (based on escalation of FFTF cost)
  - DOE has not built a new reactor in over two decades

MTS will be located in the 32,000 ft^2 LANSCE "Area A" experiment hall

Existing assets include:

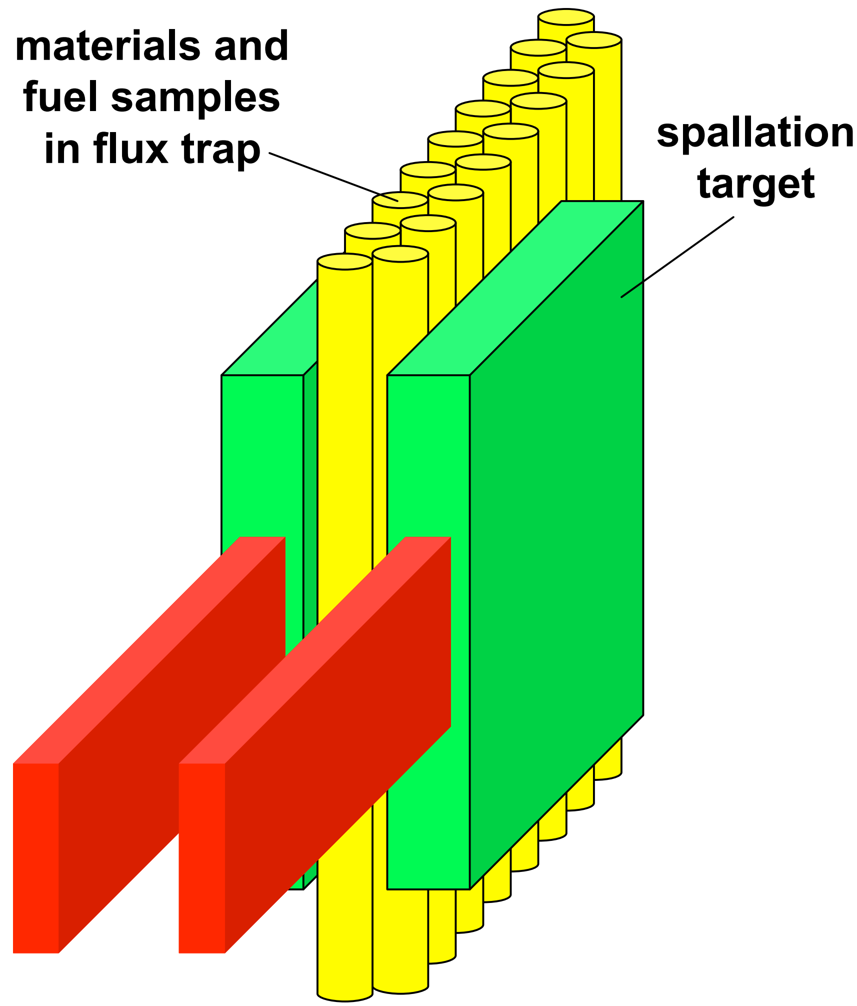
- 800-MeV, 1-mA proton linac
- 30-T crane
- 12 MVA electrical power
- Secondary cooling loops
- Steel and concrete shielding



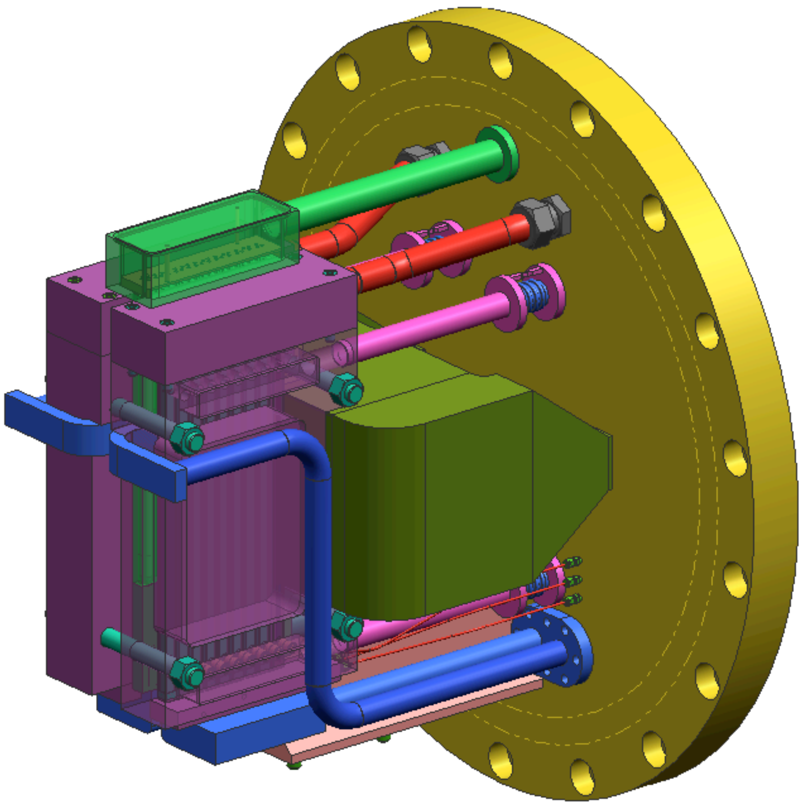
The LANSCE accelerator and Area A have a replacement cost of $1B. Utilization of this unique resource significantly reduces MTS capital costs.

MTS uses the pulsed LANSCE beam to illuminate two target sections, creating a “flux trap” in between

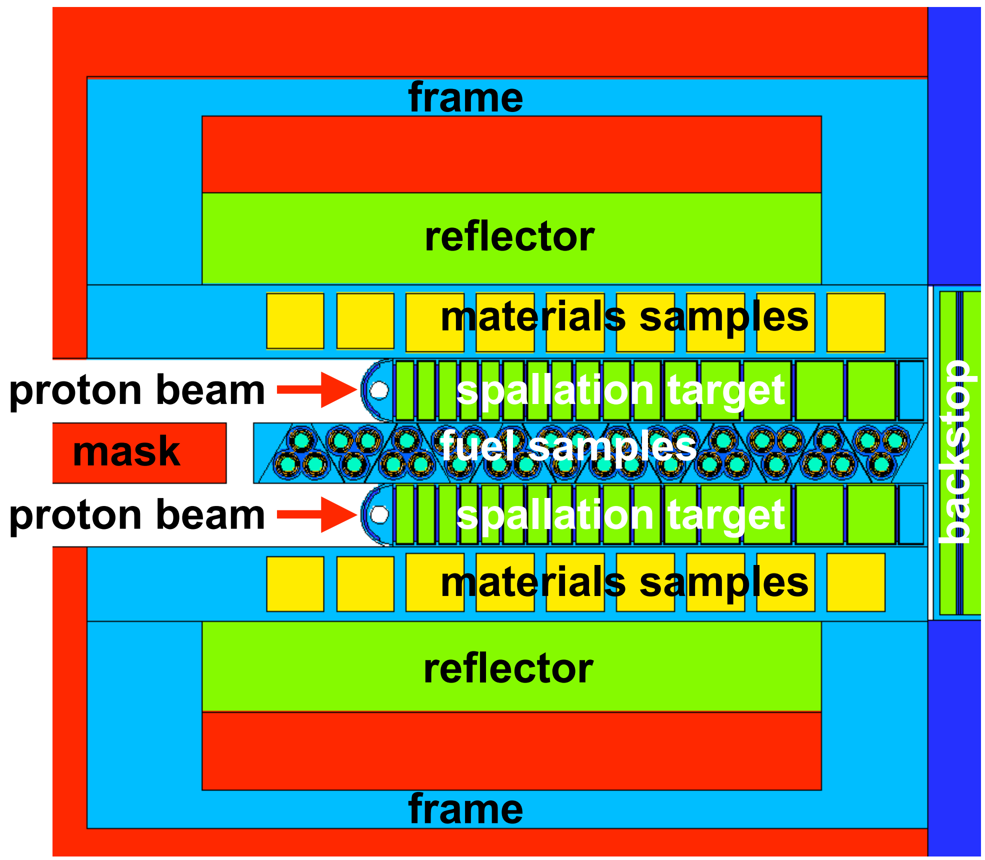
- The 1.5-cm-wide by 6-cm-high proton beam spot is directed on to a target section during a 625-μs macropulse
- Between macropulses, the beam is switched to the other target section
- 50 macropulses hit each target section every second



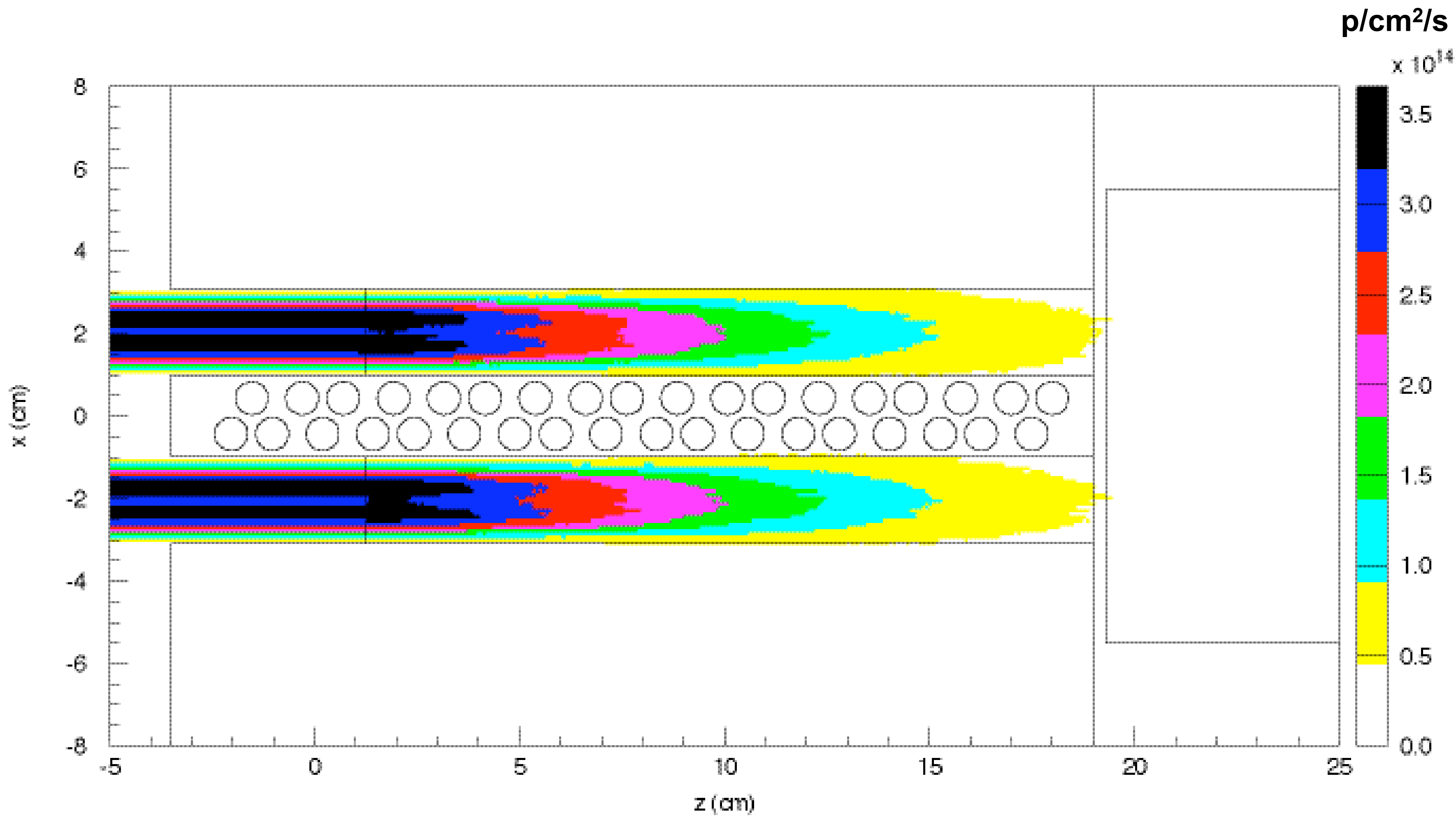
A series of nested inserts comprises the target/sample assembly



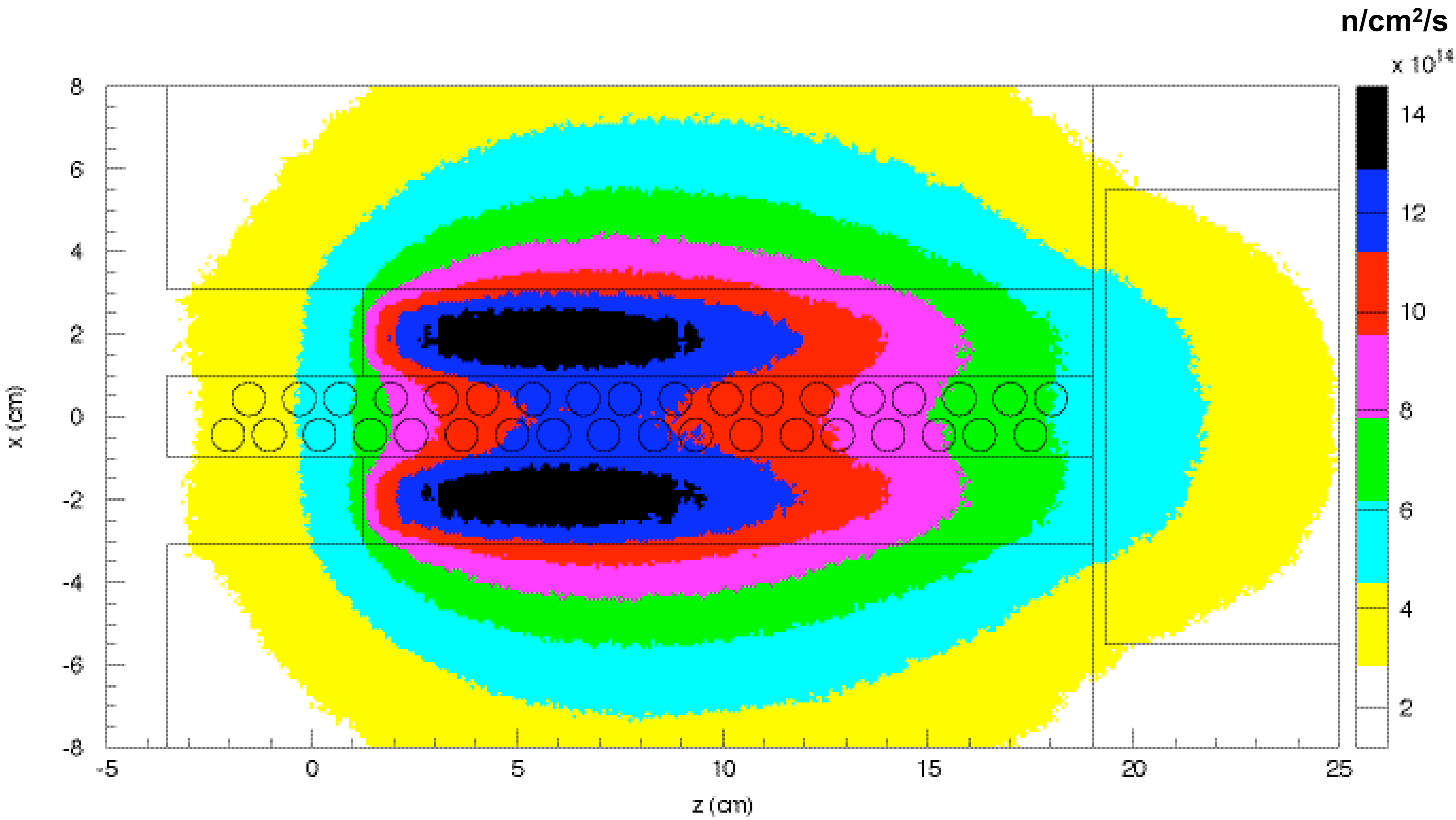
Horizontal section at mid-plane



Proton flux distribution at target mid-plane



Neutron flux distribution at target mid-plane



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MCNPX and CINDER'90 are the "work horse" codes for the MTS neutronics design

- MCNPX calculates:
  - Particle fluxes and spectra
  - Energy deposition (heating rates)
  - Fission rates, burnup, fission heating
  - Radiation damage (atomic displacement and He production rates)
  - Personnel dose through shielding from prompt radiation
- CINDER'90 calculates:
  - Radionuclide inventories for safety and permitting
  - Decay heat
  - Decay gamma spectra and source terms

MCNPX code improvements for MTS application

- Incorporation of updated intranuclear cascade models
  - the latest models (CEM03, INCL) show better agreement with experimental data on residue yields
- In-line tally edits of spallation product yields
- Continued improvement in the functionality of the burnup capability (i.e., embedded CINDER'90)
- Refine the capability to co-plot geometry and mesh tallies

CINDER’90 code improvements for MTS

- LANL (MTS & Lujan), ORNL (SNS), ANL (IPNS) are collaborating to develop a standardized “script” for running CINDER’90
- Need to include light charged particle emission from ternary fission in the library
- Extend the library to higher energy (25 MeV → 150 MeV)
- Extend the code and library to treat proton reactions
- Continuous-energy fission product yields instead of three coarse groups

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Helium production from actinide fission

- High-energy neutron tail in MTS may cause higher helium production rate in fuel
- Depending on fuel form, helium production may be dominated by inert component, or by actinide
- Helium production in actinides comes from ternary fission channel

Helium production in actinides comes from ternary fission channel

- ENDF evaluations do not contain He production from ternary fission
- ENDF-349 (England and Rider, 1993) tabulates He production by ternary fission for 20 nuclides at three energies (thermal, fission spectrum, and 14 MeV)
  - 235U thermal = 0.198%
  - 235U fis spec = 0.174%
  - 235U 14-MeV = 0.135%
  - 239Pu thermal = 0.216%
  - 239Pu fis spec = 0.194%
  - 239Pu 14-MeV = 0.238%

Ternary fission data in ENDF-349 derived from report by Madland and Stewart (LA-6783-MS)

- Sparse experimental data were available to the authors in 1977, from which they derived an empirical formula of ternary fission yields
- Uncertainties are quoted at ±25%, and experimental data are thought to underestimate true yields due to the low-energy cutoff of the charged particles detectors

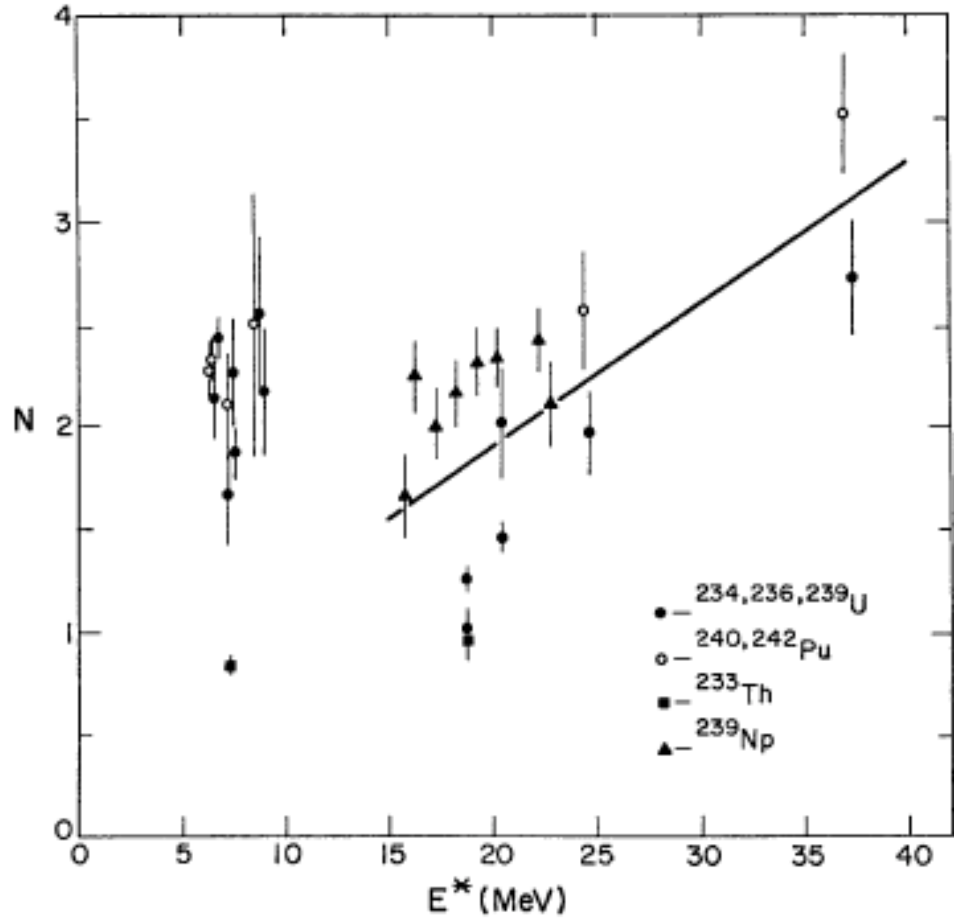
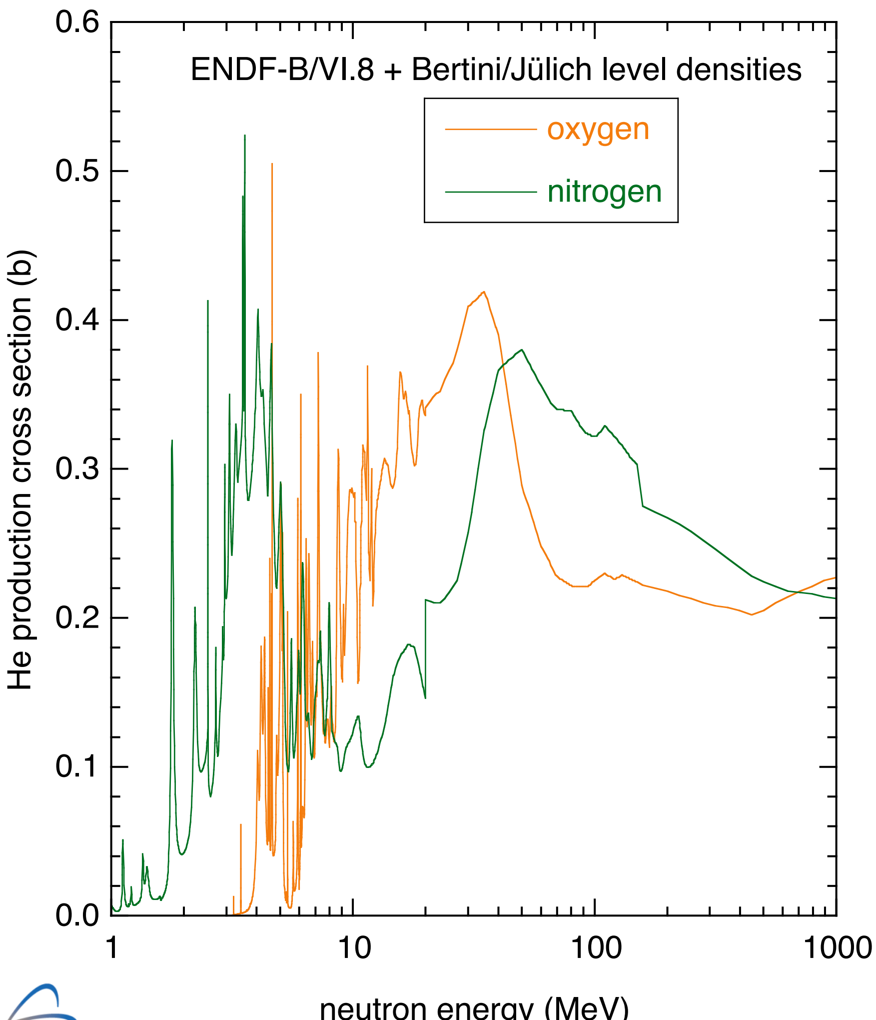
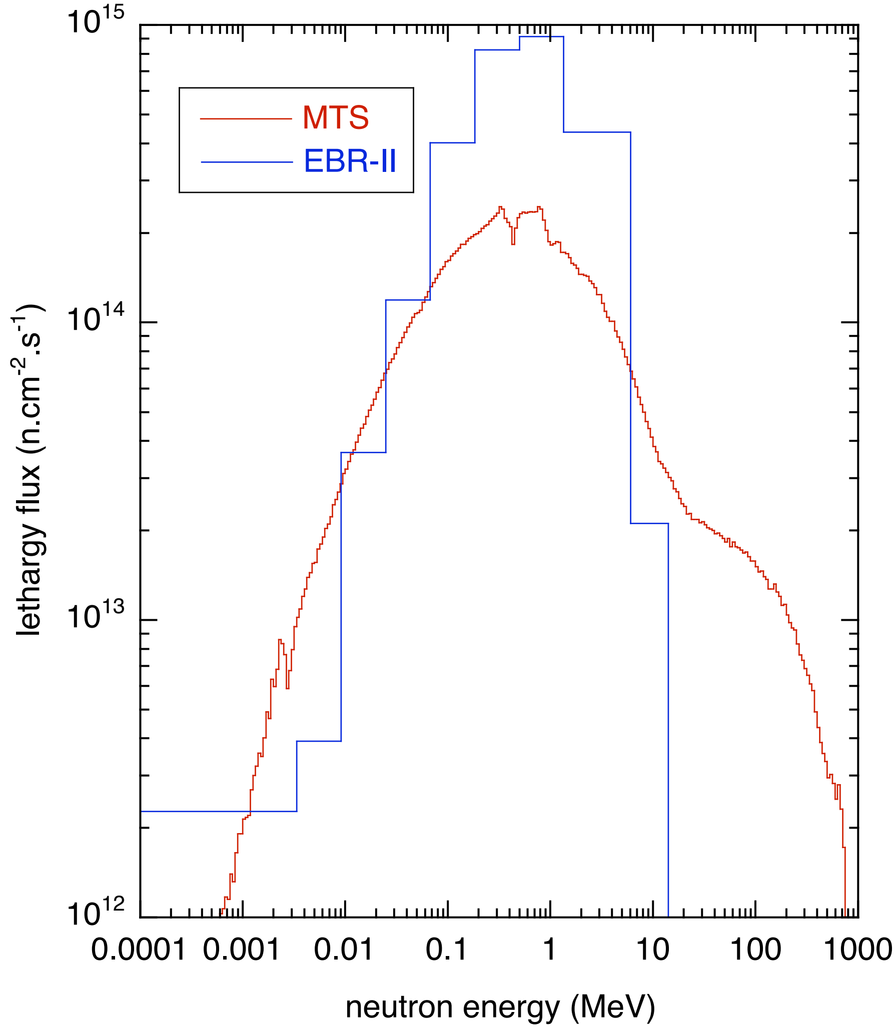


Fig. 1.

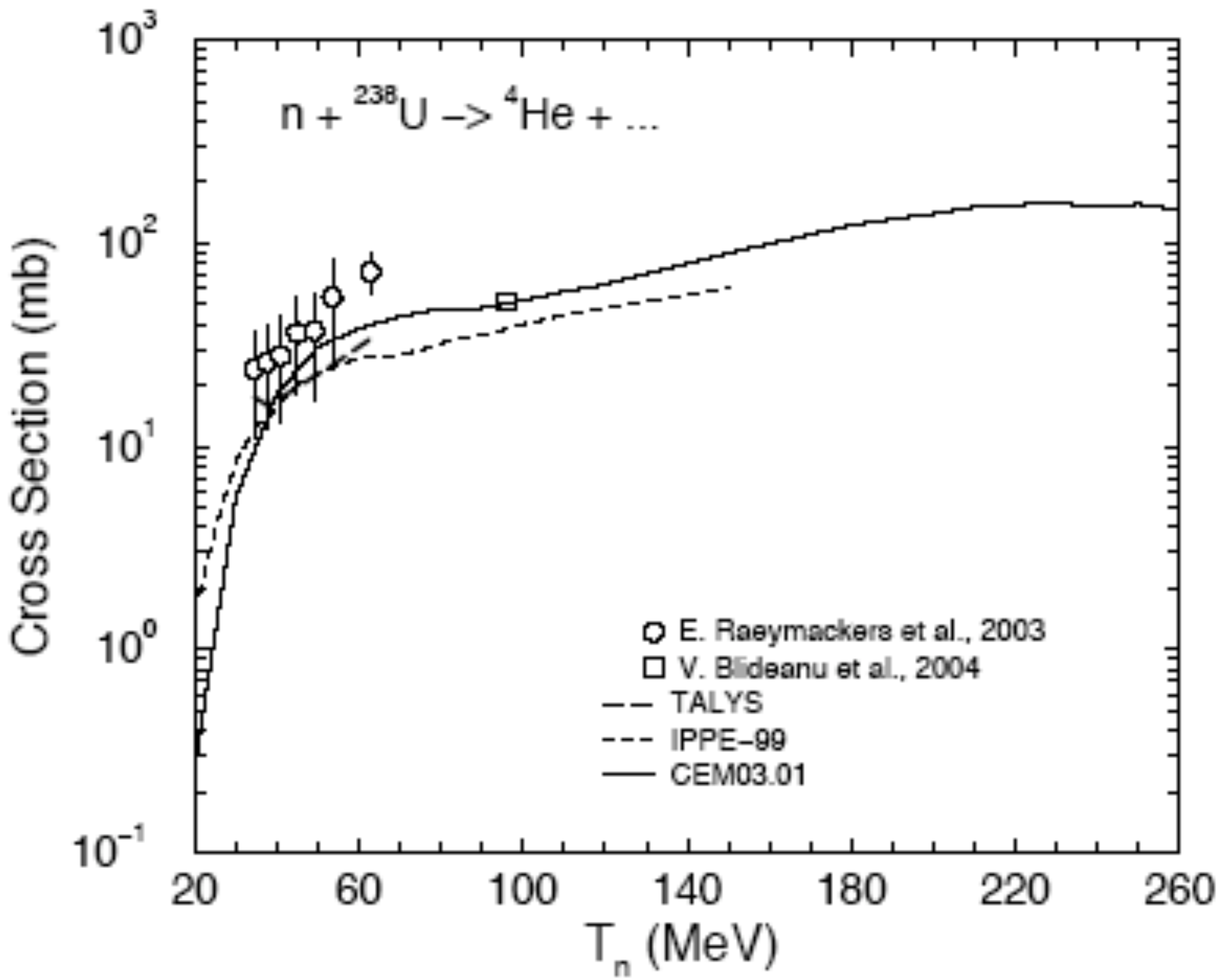
Light charged particle yield per 1000 fissions, N, vs the excitation energy, E*, of the indicated compound systems.

In certain fuels, the non-actinide component may be a significant source of helium production





Mashnik has produced $^{238}U(n,x\alpha)$ cross section using his CEM03 code



He production is sensitive to both fuel form and neutron spectrum

	MTS			EBR-II		
	Uranium	Other	Total	Uranium	Other	Total
UO_2	100	580	680	40	180	220
UN	130	770	900	50	680	730
U-10Zr	160	30	190	60	0.7	61

Values are appm He/year, normalized to a flux of 1×10^{15} n/cm^2/s.

Ternary fission data need updating and inclusion into ENDF

- Search of experimental data since 1977
- New experiments where data are lacking
- Inclusion of light charged particle emission by ternary fission in ENDF

New 150-MeV evaluations would benefit MTS

- Tantalum -- cladding for tungsten target, possible "monolith" material
- 238U -- possible spallation target material
- Molybdenum -- alloying element of uranium

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The applicability of the Lindhard model to the spallation environment still needs study

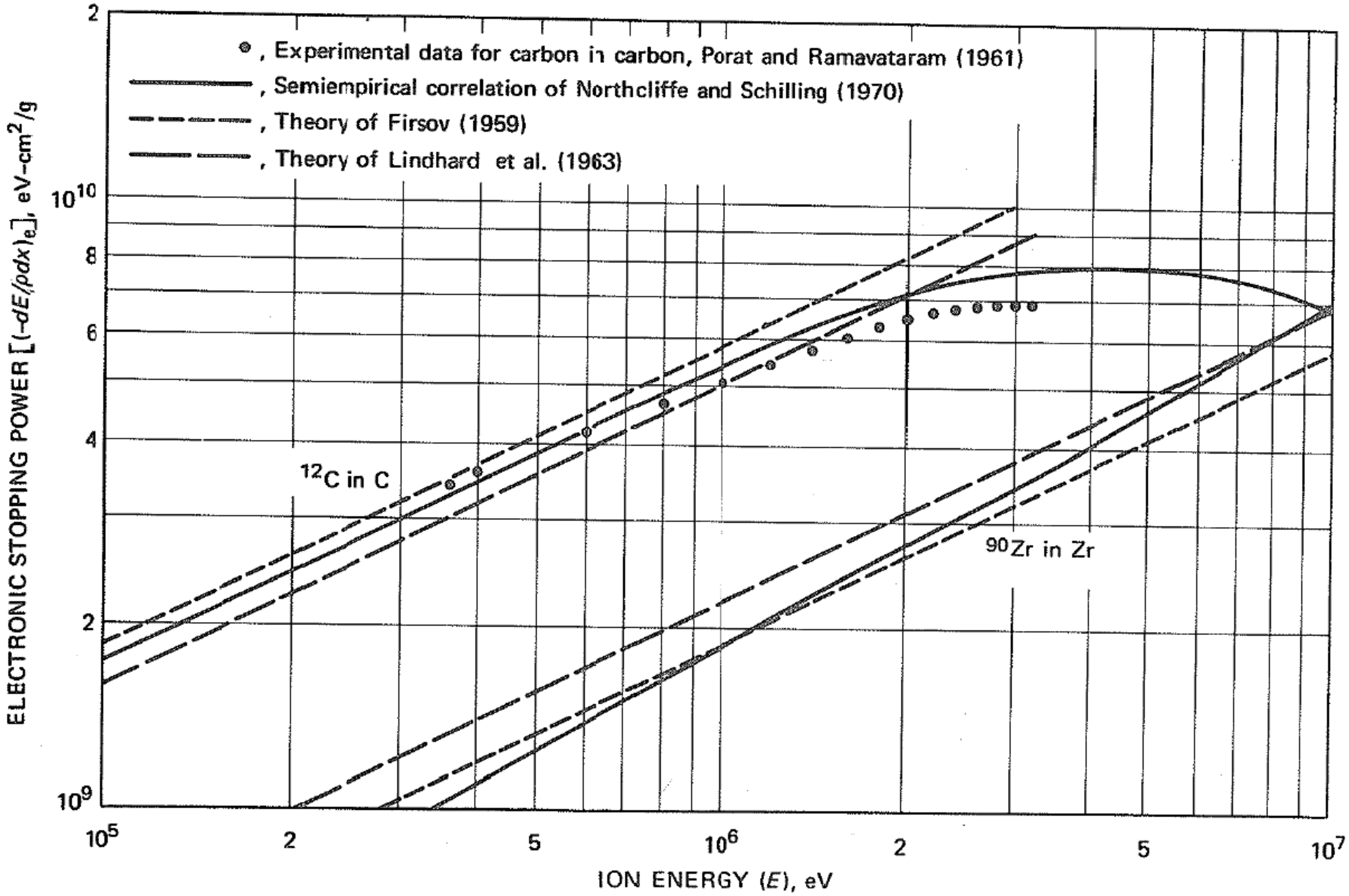

Fig. 4 The electronic stopping power of ^{12}C ions in carbon and of ^{90}Zr ions in zirconium.

Back-up slides

High-level function and requirements of the Materials Test Station

- **Function:** Provide an irradiation test bed for qualifying advanced fuels and materials for fast spectrum transmuters and the next generation of fast reactors

Requirements:

- Produce a neutron spectrum similar to that of a fast reactor
- Provide a peak fast neutron flux of at least 1×10^{15} $n.cm^{-2}.s^{-1}$
- Provide an irradiation volume sufficient to achieve 1 kW/cm^3 or greater fission heating in 20 linear cm of test fuel (highly enriched TRU)
- Run sufficiently long and reliably to achieve fuel burnups of 3% per year or more, and generate at least 10 dpa/y radiation damage in iron in the peak flux region
- Capability for prototypic fast reactor temperature and coolant environment

Proof of performance of the fuel and cladding is necessary for licensing of transmuters

- Transmutation fuels containing the higher actinides are now being developed
- First test pins made only in the last two years
- Qualification is a long process (~10 years or more)
- Irradiation testing in a prototypic environment is essential for fuel and cladding qualification

Irradiation testing in a thermal spectrum gives high fission rate but minimal clad damage, thereby missing any fuel-clad interaction failure mechanisms.